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Washington, D.C. 20555

ATTENTION: MR. T. R. QUAY

SUBJECT: AP600 PCS DESIGN BASIS ACCIDENT "ROADMAPS"

Dear Mr. Quay:

The attachment to this letter provides several tables which were developed to assist the ongoing review of the AP600 Passive Containment Cooling System design basis analyses. The tables outline the PCS DBA methodology and have been revised to reflect items discussed in recent meetings between Westinghouse and the Containment Systems and Severe Accident Branch. This document was prepared in response to an NRC staff request and is intended to assist the review currently underway by the Containment Systems and Severe Accident Branch.

Please contact me on (412) 374-4334 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

Attachment

cc: D. Jackson, NRC
J. Kudrick, NRC
E. Throm, NRC
N. J. Liparulo, Westinghouse (w/o enclosures/attachments)

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**Table 1: PIRT Application to Evaluation Model: Inside Containment - All phases**

| Module | PIRT Phenomena | Ranking for Containment | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusions | Applicability of LST with Respect to Phenomena | Validation of Modeling Method and/or WGOTHIC | Use of Validation Results in this Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|---|---|---|---|---|---|
| I. Volume | A. Multi-component Compressible Gasses | H | Gas constituents in the governing equations | All tests analyzed with WGOTHIC | Complete<br>NTD-NRC-94-4260<br>Enclosure 1: GOTHIC Technical Manual describes governing equations<br>Enclosure 2: GOTHIC User's Manual describes how to invoke various gasses<br>Enclosure 3: GOTHIC Qualification Report provides large database of tests with air, hydrogen, and helium<br>NTD-NRC-95-4462<br>EPRI Report RA-93-10, GOTHIC Design Review, Final Report<br>WCAP-14382 validates WGOTHIC with separate effects, integral tests with steam *and* air~~, and helium~~ | Effects of multicomponent compressible gasses are correctly included in governing equations | LST includes air *and* steam, ~~and helium~~ | WGOTHIC has been validated with the LST | Governing equations in WGOTHIC are a valid representation of compressible, multicomponent gas behavior<br>Maximum Technical Specification pressure used in conjunction with 0% relative humidity. | Bounded |
| | B. Buoyancy | H | Buoyancy forces are included in the lumped parameter junction governing equations | LST *internal boouyant flows*<br>~~Hugot tests~~<br>~~Siegel & Norris tests~~ | Complete<br>*WCAP-14326, Separate effects test*<br>WCAP-14382, *for integral tests* | Lumped modeling overmixes noncondensibles above operating deck thereby reducing heat removal from vessel when PCS is dominant<br>Distributed parameter modeling shows good agreement with 550 node LST model.<br>Modeling of buoyancy and entrainment is acceptable. | Steam injection point elevation and direction effects tests were performed<br>LST has prototypical buoyancy driving forces and covered the range of Froude numbers for LOCA | WGOTHIC has been validated with the LST | ~~Mixing and stratification resulting from buoyancy driven flow will be studied in the WGOTHIC Applications WCAP~~<br>*See boxes for line IV.A.* | ~~Sensitivity to mixing will be provided in applications WCAP~~<br>*Bounded* |

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| | C. Flow Field Stability or Stratification | L | Mixing within the containment upper regions and mixing between the upper and lower portions of the containment | LST | NTD-NRC-95-4459, Stratification and Mixing Effects on AP600 Passive Containment Cooling System DBA<br>WGOTHIC Applications Document<br>ACRS T/H Subcommittee Meeting, March 29-30, 1995 (to be documented in letter report) | Blowdown is the same as standard plants.<br>Long-term LOCA is driven by buoyant plume and LST covers range for AP600.<br>MSLB is well mixed due to high velocity jet.<br>Distributed parameter modeling shows good agreement with 550 node LST model.<br>Modeling of buoyancy and entrainment is acceptable. | Upper and lower regions of containment represented in the LST | WGOTHIC model has been validated with the LST | ~~Mixing and stratification resulting from buoyancy driven flow will be studied in the WGOTHIC Applications WCAP~~<br>*See boxes for line IV.A* | ~~Sensitivity to mixing and break size will be provided in applications WCAP~~<br>*Bounded* |
| | | | | | | | | | | |
| II. Surface | A. Liquid Film Heat Transfer | M | Thermal conductivity of liquid film for film temperature drop | Chun & Seban<br>Wisconsin Condensation Tests | Complete<br>NTD-NRC-94-4100, Enclosure 2 "Liquid Film Model Validations"<br>WCAP-14382 §2 | The Chun and Seban data provides a basis for film thermal conductivity. | Internal and external liquid film effects are represented in the LST | All validation performed with WGOTHIC includes the small effect of film temperature drop | Nominal wavy-laminar and turbulent Chun and Seban correlations used as appropriate | Negligible effect since resistance across film is small part of total resistance |
| | B. Liquid Film Stability/Coverage | L | Condensation on the interior surface of containment | LST<br>Wisconsin Condensation Tests | WCAP-13307<br>I.K. Huhtininemi, "Condensation in the Presence of Noncondensible Gas: Effect of Surface Orientation," Ph.D. Thesis, Univ. Wisconsin, 1992 | Internal films are stable since containment shell slope is in excess of 1°. Droplet formation improves mass transfer | Prototypical surfaces included in the LST<br>Separate effects studied in Wisconsin Condensation Tests | WGOTHIC model has been validated with the LST | Shell slopes modeled with WGOTHIC exceed 1°<br>Condensate on containment is returned to the IRWST<br>Benefits of droplet formation neglected | Bounded |
| | C. Liquid Film Enthalpy Transport | M | Liquid film energy conservation equation | LST<br>Wisconsin Condensation Tests | Complete<br>WCAP-14382 §2.4, 2.5 show equations for liquid film<br>WCAP-14190 | Subcooling is negligible compared to energy transported to liquid field | Prototypical surfaces included in the LST<br>Separate effects studied in Wisconsin Condensation Tests | WGOTHIC model has been validated via the LST and Wisconsin Condensation Tests | Temperature profile through film considered in solution | Negligible, film is at or near saturation temperature |

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| | D. Free Convection Heat Transfer | L | McAdams Flat Plate Correlation<br>~~Mixed Convection~~ | LST | WCAP-14190 page 2-7<br>WCAP-14326 page 4-1<br>WCAP-14382 §8 | *Convective* heat transfer is not significant in comparison to mass transfer | Prototypical internals<br>Range of validation defined in WCAP-14382 §9.2 | WGOTHIC model has been validated with the LST | *A conservative bias of 0.741 times the nominal correlation is used* | *Bounded by conservative bias* |
| | E. Forced Convection Heat Transfer | L | ~~Lumped~~ - Not modeled<br>~~Distributed - flat plate forced convection, mixed convection~~ | LST | WCAP14190 page 2-7<br>WCAP-14326 page 4-1<br>WCAP-14382 §8 | Convective heat transfer is not significant in comparison to mass transfer | Prototypical internals<br>Range of validation defined in WCAP-14382 §9.2 | WGOTHIC model has been validated with the LST | ~~Lumped~~ - Forced convection heat transfer not considered<br>~~Distributed - Nominal flat plate correlation~~ | ~~Lumped~~ - Bounded by neglecting forced convection<br>~~Distributed - Bounded by code uncertainty~~ |
| | F. Radiation Heat Transfer | L | Not modeled | LST | WCAP-14190 page 2-8 | Temperature differences within containment are small enough that radiative heat transfer is low | Prototypical internals and temperature driving forces modeled in LST | WGOTHIC modeling of LST neglected radiative heat transfer | Not modeled | Bounded |
| | G. Free Convection Mass Transfer | H | ~~Lumped~~ - Heat and mass transfer analogy based on McAdams flat plate heat transfer correlation<br>~~Distributed - Heat and mass transfer analogy using the mixed convection correlation~~ | LST<br>Wisconsin Condensation Tests | WCAP-14190 page 2-8<br>WCAP-14326 §3.8, 3.9, 4.3<br>WCAP-14382 §4.3, 8.2 | Mass transfer conservatively biased<br>mean=0.983<br>$\sigma$=0.187 | Prototypical internals and temperature driving forces modeled in LST<br>Range of validation defined in WCAP-14382 §9.2 | LST internal data as a separate effect<br>Wisconsin Condensation Tests | *A conservative bias of 0.741 times the nominal correlation is used* | *Bounded by conservative bias* |
| | H. Forced Convection Mass Transfer | L | ~~Lumped~~ - Not modeled<br>~~Distributed - Heat and mass transfer analogy based on flat plate forced convection in the mixed convection correlation~~ | LST<br>*Wisconsin Condensation Tests* | WCAP-14190 page 2-8<br>WCAP-14326 §3.8 | Mass transfer conservatively biased<br>mean=0.968<br>$\sigma$=0.203 | Prototypical internals and Froude numbers modeled in LST<br>Range of validation defined in WCAP-14382 §9.2 | ~~Lumped~~ - Validated WCAP-14382 §8<br>Dominant only during first seconds of *LOCA* transient<br>~~Distributed - Dominant only during first seconds of transient~~ | ~~Lumped~~ - Not modeled<br>~~Distributed - Mixed convection correlation combining free and forced convection with a conservative bias~~ | *Bounded by neglecting forced convection* |
| | | | | | | | | | | |

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| III. Solids | A. 1-D Transient Conduction Heat Transfer | H | GOTHIC conductors used to model internal heat sinks include a 1-D conduction solution | CVTR<br>LST with internal heat sinks | NTD-NRC-94-4260 "GOTHIC Containment Analysis Package, Version 3.4e, Volumes I-III," Volume 1, §6 describes the 1-D conduction solution used.<br>WCAP-14382 provides validation with LST | Use of Uchida with 1-D conductor for internal heat sinks is conservative and consistent with SRP guidelines | Internal LST heat sinks are modeled using GOTHIC conductors with Uchida for condensation | WCAP-14382 shows validation results with internal heat sinks modeled with Uchida | SRP guidelines are an acceptable approach.<br>Conservatively bounded material properties are used for AP600 internal conductors.<br>Surface area and volume of internal heat sinks are conservatively underestimated. | Bounded |
| | | | | | | | | | | |

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| IV. Inter-Module | A. Convection | L | Governing [illegible] for lumped p[illegible]r volumes connected with junctions and node-to-node connections for distributed parameter | LST | NTD-NRC-95-4459, Stratification and Mixing Effects on AP600 Passive Containment Cooling System DBA<br>WCAP-14382 §5.3<br>WGOTHIC Applications Document<br>WCAP-14190 §9 | *Fr scaling shows MSLB expected to be well mixed. Flow area restriction in evaluation model limits steam access to below deck during short MSLB releases*<br>Lumped - Overmixing penalizes heat and mass transfer when PCS is dominant (*LOCA longterm*)<br>Distributed - 375 node LST ~~is sufficiently accurate with~~ *has* slight bias towards overmixing - can bias mixing with flow areas *LOCA blowdown pressurizes SG compartment sufficiently to drive flow throughout lower compartments. Natural circulation develops post-blowdown* | Applicable to above deck circulation and heat and mass transfer correlation validation *LST has been used to develop rationale for bounding approach on mixing* | *Mixing biased toward worst case for each accident.*<br>*A sensitivity using nominal flow area in the AP600 will be provided in the Applications WCAP to quantify conservative bias.* | Restrict mixing between upper and lower regions of containment when mixing is a benefit (*LOCA second peak*) | Bounded *by biasing mixing in conservative direction for each accident* |

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|---|---|---|---|---|---|---|---|---|---|---|
| | B. Conduction | H | Climes include 1-D conduction model used for conduction through containment shell | Comparison to theoretical solutions | Complete. WCAP-14382 §2.5 shows the governing equation and discretization for 1-D conduction | The 1-D conduction model is correctly programmed into WGOTHIC | 1-D conduction used to model heat transfer through the LST shell, which neglects the additional heat removal by azimuthal conduction from dry to wet surfaces. | WCAP-14382 §4.1 contains validation of the 1-D conduction equations in Clime subroutine | 1-D conduction equation is part of the Clime subroutines used for heat transfer through the shell. Effects of degradation of inorganic zinc paint are included in material properties. Conservative material properties used. Using 1-D conduction conservatively neglects azimuthal conduction from dry to wet stripes. | Bounded |
| | C. Form and Friction Losses | L | Inter-compartment losses | Standard experimentally based loss coefficients | *WCAP-14382 §6.0 describes methods used to model LST* | *Use of standard loss coefficients through grating is validated* | *Simplified representation of lower compartments* | *See IVA.* | Restrict mixing between upper and lower regions of containment when mi.ing is a benefit. *Increase mixing when it is a penalty. (See IVA.)* | *Bound effects of mixing.* |

**Table 2: PIRT Application to Evaluation Model: Outside Containment - LOCA - All Phases**

Date last modified: August 28, 1995

| PIRT Phenomenon | Ranking for Riser[(1)] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusions | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|---|---|---|---|---|
| **I. Module Volumes** | | | | | | | | | |
| A. Multi-component compressible gasses | H | Gas constituents in the governing equations | All tests analyzed with WGOTHIC | Complete<br>NTD-NRC-94-4260<br>Enclosure 1: GOTHIC Technical Manual" describes the governing equations<br>Enclosure 2: GOTHIC User's Manual describes how to invoke various gasses<br>Enclosure 3: GOTHIC Qualification Report provides a large database of tests with air, hydrogen, and helium.<br><br>NTD-NRC-95-4462<br>EPRI Report RA-93-10, GOTHIC Design Review, Final Report<br><br>WCAP-14382 validates WGOTHIC with separate effects and integral tests with steam, air, and helium gases.<br><br>~~"Revision will be made to correct typographical errors.~~<br><br>*"Westinghouse will expedite revised documentation which addresses Peer Review results.* | Effects of multi-component compressible gasses are correctly included in governing equations. | LST includes air, steam, and helium. | WCAP-14382 provides validation of external annulus modelling methods. | Governing equations in WGOTHIC are a valid representation of compressible, multi-component gas behavior.<br><br>*Maximum Tech Spec value of environment temperature is used as the boundary condition in WGOTHIC models.* | ~~Included in code uncertainty~~<br><br>*Bounded* |
| B. Buoyancy | H | Buoyancy forces are included in the lumped parameter - junction ~~governing~~ equations | - LST without fan running<br>- Hugot tests<br>~~- Eckert and Diaguila tests~~<br>- Siegel and Norris tests | Complete<br>WCAP-14382 §7.2.2 identifies the relevant priority ~~test~~ *LST* with fan off to support external annulus modelling.<br><br>*WCAP-14326 § 3.1, 3.3*<br><br>*NTD-NRC-94-4083*<br>*W/NRC PCS Meeting*<br><br>~~To be issued.~~ *As part of the* Applications Report, ~~Document~~ the sensitivity to Kloss (uniform and nonuniform) and nominal delay time *will be confirmed using the final evaluation model.* | The external annulus predictions provide comparisons to ~~reasonable agreement with LST and associated uncertainties can be accommodated in the DBA.~~<br><br>*External separate effects with buoyancy driven flows are validated.*<br><br>*Weak sensitivity to Kloss (uniform and nonuniform) has been shown.* | All *7 baseline and 7 confirmatory* LST in the HWRF program were run with the fan off.<br><br>The LST priority test 214.1 *(fan off)* has been used for validation. | WGOTHIC has been validated with LST *214.1* with natural convection driving the annulus flows in WCAP-14382 §5, 6, 7, 8. | The external annulus is modelled with pressure boundary conditions at the inlet and outlet, such that the imposed ΔP is ≤ ~~equal to~~ the external density head *driving force. Thus,* the initial annulus air flow is conservatively established at a *slightly* negative value *(directed downward in the annulus).*<br><br>The momentum equation is solved, balancing the buoyancy driving head with the unrecoverable losses through the annulus. | Nominal loss coefficient is used.<br><br>Weak sensitivity to loss coefficient.<br><br>Conservative initial air flow bounds postulated annulus flow start-up concerns. |

| PIRT Phenomenon | Ranking for Riser[2] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusions | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|---|---|---|---|---|
| C. Flow field stability or stratification | L | External flow path is a 1D hydraulic model | - *LST riser*<br>- *External flow path ΔP test*<br>- *Eckert and Diaguila*<br>- *Siegel and Norris*<br>- *Hugot* | Complete<br>NTD-NRC-95-4414<br>RAI 952.102 response:<br>WCAP-14190, Section 7.2 and 7.3 provide momentum and energy scaling for justification.<br><br>WCAP-14382, §8 provides validation using 1D flow path for annulus.<br><br>~~To be issued: Applications Report Document sensitivity to Kloss (uniform and nonuniform) and nominal delay time.~~<br>*See block on line above for loss coefficient study results.* | Potential for local recirculation at downcomer inlet to affect total air flow at AP600 operating conditions is **negligible** *since there is minimal energy or momentum in the downcomer.*<br><br>Small sensitivity to fairly large Kloss effects | N/A<br><br>*Successful modeling of the external annulus with a 1D flow path shows ability of 1D model to predict riser phenomena.* | *The downcomer flow area is large to act as a reservoir within which pressures can equalize, providing a relatively uniform inlet for the annulus.* Use of ~~1D flow path is justifiable~~ Since heat transfer and momentum in the downcomer, relative to the riser, is so small that the possibility of downcomer instabilities is insignificant. *Flow is primarily one-dimensional in nature; therefore, use of 1D flow path is justifiable.*<br><br>*Since fully developed turbulent flow develops in annulus before the baffle heats up, there is no potential for hot-baffle-induced flow instability to impact* ~~impact on~~ start-up of annulus air flow. | External flow path is modelled as 1D lumped parameter | Negligible effect<br><br>**Weak sensitivity to external loss coefficient shows** *pressure is not sensitive to postulated inhibitors to external flow.* |
| | - | Fog in annulus | - | Complete<br>NTD-NRC-94-4100, Enclosure 1<br>"Radiation Heat Transfer Through Fog in the PCCS Air Gap" | Justification for neglecting effect of fog in annulus since effect of radiation capture by fog in AP600 has a negligible effect on the annulus air temperature and overestimates the heat transfer to the baffle. | Database consistent with AP600 expectations *for external annulus conditions.* | Effect of fog neglected in WGOTHIC models | Negligible effect on answers | Negligible effect |
| | - | Effect of wind-induced recirculation and stratified atmosphere is neglected | Literature | Complete<br>NTD-NRC-94-4166<br>"AP600 Containment Plume Investigation" | Quantification of potential for recirculation of effluent and thermally stratified atmosphere to affect cooling rates gave bounding recirculation fraction, and a resulting sensitivity showed no significant containment pressure effect. | LST was run in no-wind (<5 mph) conditions | External pressure boundary condition is unadjusted for these effects | Assumption of no recirculation due to these effects has negligible impact on pressure prediction | Negligible effect |
| | | Effect of wind-induced turbulence is neglected | Wind tunnel tests | Complete.<br>NTD-NRC-95-4467<br>"Analysis of AP600 Wind Tunnel Testing for PCS Heat Removal" | Oscillating flows for worst case site with least positive mean wind coefficient slightly increase heat removal rates from containment. Less severe terrains with more positive wind coefficients show significant increases in heat removal. | Not applicable | External pressure boundary condition is unadjusted for these effects | Assumption of no wind is bounding for pressure prediction | Bounded |

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|---|---|---|---|---|---|---|---|---|---|
| **II. Module Surface** | | | | | | | | | |
| A. Liquid film heat transfer | M | Thermal conductivity of liquid film for film temperature drop. | Chun and Saban | Complete<br>NTD-NRC-94-4100, Enclosure 2 "Liquid Film Model Validation"<br><br>WCAP-14382 §2<br><br>~~Scaling supplement will document consistent definition of resistances inside to outside shell~~ | The Chun and Saban data provides a basis for film thermal conductivity.<br><br>The liquid film temperature drop is small. | Internal and external liquid film effects are represented in the LST. | All validation performed with WGOTHIC includes the small effect of film temperature drop. | Nominal Chun and Saban correlation is used, accounting for wavy laminar and turbulent liquid films. | Negligible effect since resistance across film is small part of total resistance. |
| B. Liquid film stability/coverage | H | Shell water coverage fractions *and applied flow rate* | - Full scale, cold 1/8 sector tests<br><br>- Hot LST measured coverage<br><br>*- Westinghouse flat plate evaporation tests*<br><br>- Vendor age/contamination *information tests* | Complete<br><br>*WCAP-12665, §3.1*<br><br>NTD-NRC-94-4247 "Method for Determining Film Flow Coverage for the AP600 Passive Containment Cooling System"<br><br>NTD-NRC-94-4286 "Supplemental Information on AP600 PCS Film Flow Coverage Methodology," *including sensitivity to 3/4 and 1/2 of bounding SSAR coverages showing well away from any cliffs in performance.*<br><br>*SSAR Rev. 4 Preliminary Markup 6.2.1.1.3 summarizes water coverage assumptions.*<br><br>*NTD-NRC-94-4089 W/NRC PCS Meeting Weak sensitivity to PCS flow rate, water coverage fraction, PCS time delay was shown.*<br><br>~~To be issued: Vendor report on effects of age and contamination.~~<br><br>~~Note: An independent review by an industry expert is also planned.~~ | *Tests with water onto surfaces up to 248F showed that the plate wet without delay, even quenching a hot plate with cold water. Evaporating films do not become unstable, even with total film dryout.*<br><br>Water coverage on dome and sidewalls as a function of time is used to bound (Figure 2) cold, full scale data and heated data from LST. The model has been validated with cold and heated tests, and bounds test data.<br><br>Model ~~adequately~~ conservatively accounts for effects of aging by using *a* ~~via its effect on~~ *the wetting angle for a new surface.* Aging increases the polarity of the surface and thus increases wetting. Surface contaminants will be minimal based on inspection and cleaning criteria. Sensitivities using approximately *3/4 and 1/2* ~~and ¼~~ of bounding SSAR coverage values show that the AP600 pressure response is relatively insensitive to further reductions in coverage below the bounding minimum evaluation model values. | Heated LST data has been used to assess heat flux effect on coverage fraction.<br><br>Measured coverage fractions on the LST were used as input boundary conditions in the WGOTHIC validation runs to validate cooling rate prediction models with test data. | Water coverage is an input boundary condition *to the WGOTHIC code. A "top-to-bottom stack" of climes is used to model each of the wetted and dry portions of the external shell. Coverage fractions are used to determine the maximum value of potentially wetted shell heat transfer surface area input to the WGOTHIC climes model. Coverage for the dome at top and mid levels is assumed to be 40% to bound full scale cold test data, where the film is thick enough that film stability does not limit coverage.*<br><br>*The wetted cross sectional area of the balance of the wetted portion where film stability limits coverage is obtained from 26.17 hrs in Table 4 of NTD-NRC-94-4247, where 100% dome coverage values show that film stability does not limit dome coverage. The Table 4 values have not been adjusted to account for the reduced evaporation associated with the assumed 40% coverage on the dome. Therefore, the coverage fraction assumed in the DBA bounds all times during the PCS DBA.*<br><br>*Weak sensitivity to the input water coverage shows that minor perturbations in this assumption do not impact pressure predictions.* | The validated conservative water coverage model is used to calculate input boundary conditions for the PCS DBA Evaluation Model.<br><br>Bounding minimum water coverage fractions are used | Bounded |

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|---|---|---|---|---|---|---|---|---|---|
| | | Shell wetting time delay | - Full scale, cold 1/3 sector tests | *NTD-NRC-94-4083* <br> *W/NRC PCS Meeting* <br><br> A-written *The discussion in the boxes to the right* will be provided in the applications report. | *Weak sensitivity to PCS flow rate, water coverage fraction, PCS time delay was shown.* | LST 219.1 has water onto hot surface and thermocouple temperatures show the surface readily rewets during the high flow portion of the non-prototypical oscillating flow. <br><br> Videotapes of a shakedown LST with a somewhat higher flow rate show water behavior applied to 240F surface. The observations showed that the advancing film front sizzled as it was boiled away, and readily flowed down as wide stripes after the surface fell below the leidenfrost temperature. | Input Boundary Cond*on delay time produces a conservative result. <br><br> Earlier water application does not adversely impact air flow initiation because there is would be a net improvement in due to evaporative cooling. <br><br> The effect on annulus air temperature and vapor content of water applied to the surface is explicitly modeled in WGOTH.C 1D annulus calculation. A sensitivity based on actual chronology with earlier wetting will be provided in the Applications report. | Since the outer surface temperature *does not increase significantly* is not hot until after water reaches the *containment shell* surface in real time, cold tests are acceptable to determine delay times. Delay time to wet the external surface is conservatively bounded by using time to reach steady state coverage fractions from the cold full scale test. This conservative delay time thus neglects *integrated* heat removal during about *10* & minutes of actual water application *during the period when steady state film coverage is developing.* when surface temperature has not significantly increased. <br><br> Time delay used bounds all postulated effects | Bounded |
| C. Liquid film subcooling | M | Liquid film energy conservation equation | Large Scale Tests | Complete <br> WCAP-14382 §2.4, 2.5 show equations for liquid film | Inclusion of convective term in energy equation accounts for liquid film subcooling effect on LST dome heat fluxes. | LST covers range of liquid film subcooling expected for AP600. <br><br> Although a majority of the LST have higher fractions of energy removed by subcooling than AP600, the LST is valid for *developing a bounding approach for AP600* validation of physics and ph.,.mena since a scalable liquid film enthalpy transport model is used. | WCAP-14382, p. 8-6 discusses validation of LST heat flux distribution predictions over the dome. | WGOTHIC uses an appropriate set of governing equations for liquid film. Subcooling accounts for a small fraction (~5%) of the AP600 heat removal. | Negligible affect since mechanism accounts for only small fraction of AP600 heat removal. |
| D. Free convection heat transfer | L | Mixed convection correlation which reduces to the McAdams correlation, at high $Gr/Re^{2.7}$, with characteristic length in Gr number based on channel diameter | - Hugot tests <br> - Eckert and Diaguila tests <br> - Siegel and Norris tests <br> - Westinghouse LST - dry external heat transfer | Complete <br> WCAP-14190 <br> Quantifies AP600 fraction of heat removed by convective heat transfer. <br><br> NTD-NRC-95-4397 <br> Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus <br><br> *WCAP-1?326 separate affects tests validation* | *Free convective heat transfer can be neglected in the AP600 riser.* accounts for a small fraction of total heat transferred. <br><br> See also forced convection heat transfer <br><br> *The mixed convection correlation predicts the data with a conservative mean bias of 2.4%.* | *Once the outer shell heats up to at least 2F above ambient, the AP600 annulus operates in forced convection.* <br><br> LST includes tests with and without fan on, covering the annulus from *mixed* free convection through forced convection dominated regimes. | Mixed convection correlation provides good agreement with annulus conditions in the LST. | Mixed convection correlation reduces to forced convection at high *low* $Gr/Re^{2.7}$, consistent with expectation for AP600 annulus conditions. <br><br> *A conservative bias of 0.83 times the nominal correlation is used.* | Negligible affect <br><br> *Bounded* |

| PIRT Phenomenon | Ranking for Riser[(1)] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusions | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|---|---|---|---|---|
| E. Forced convectic heat transfer | L | Mixed convection correlation which reduces to the Colburn correlation at low Gr/Re$^{2.7}$ | - Hugot tests<br>- Eckert and Diaguila tests<br>- Siegel and Norris tests<br>- Westinghouse STC dry flat plate tests<br>- Westinghouse LST - dry external heat transfer | Complete<br>WCAP-14190<br>Quantifies AP600 fraction of heat removed by convective heat transfer.<br><br>WCAP-14326, §3.1, 3.2, 3.3, 3.4, 3.5, and 4.1 shows validation of the correlations with separate effects tests | *Forced convective heat transfer dominates in AP600 riser.* ~~accounts for a small fraction of total heat transferred.~~<br><br>*The mixed convection correlation is biased 2.4% conservative about the mean over the range, with a relatively large scatter due to large measurement uncertainty with small ΔT.*<br>~~μ = 0.976~~<br>~~σ = 0.278~~ | Dry LST has dominant annulus heat removal by convection<br><br>*The LST and separate effects tests cover the range of AP600 Raynold's numbers.* | WCAP-14382, §3.2.1, 4.2 provide summaries of the validation.<br><br>Although the comparisons with data show high scatter, it is attributable to high instrument uncertainty with small ΔT. The lack of any trend in the mean over the range indicates the correlation is reasonable as a basis for mass transfer analogy. Mass transfer validation, covering ΔT an order of magnitude higher, shows much less scatter. | ~~Nominal correlation (with inherent conservative bias) used in WGOTHIC.~~<br><br>*A conservative bias of 0.83 times the nominal correlation is used.*<br><br>Convective heat transfer is not a dominant ~~significant~~ heat removal mechanism for AP600 DBA. | ~~Uncertainty (scatter) is incorporated as an element of code uncertainty.~~<br><br>*Bounded* |
| F. Radiation heat transfer | L | Wall-to-wall radiant heat transfer | - Westinghouse STC dry flat plate tests<br>- Dry LST | Complete<br>WCAP-14382, §2.5 describes the radiant heat transfer model used in Climes | Dry external vessel heat transfer is validated. | Varying fractions of dry shell surface are included for all wet tests. The dry LST cases transfer a large fraction of heat by radiation to the baffle. | WCAP-14382 §7 shows selection of LST and §8 shows validation results. | Conservative property values are used in AP600 DBA. | Bounded |
| G. Free convection mass transfer | - | Empirical correlation for the Sherwood number, which is derived by dimensional analysis using the Reynold's analogy and Colburn j factors. | - Gilliland and Sherwood evaporation tests<br>- Westinghouse STC flat plate evaporation tests<br>- University of Wisconsin condensation tests | Complete<br>~~See free convection heat transfer~~<br><br>*NTD-NRC-95-4397*<br>*Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus*<br><br>*WCAP-14326 separate effects tests validation* | ~~See free convection heat transfer~~<br><br>*The annulus is dominated by forced convection mass transfer once the outer shell heats up to at least 2F above ambient during the transient.* | ~~See free convection heat transfer~~<br><br>*LST includes tests with and without fan on, covering the annulus from mixed convection through forced convection dominated regimes.* | ~~See free convection heat transfer~~<br><br>*WCAP-14382 summarizes WGOTHIC separate effects validation results (§3.2.1, 4.4)* | ~~See free convection heat transfer~~<br><br>*A conservative bias of 0.83 times the nominal correlation is used.* | ~~Negligible effect~~<br><br>*Bounded* |
| H. Forced convection mass transfer | H | Empirical correlation for the Sherwood number, which is derived by dimensional analysis using the Reynold's analogy and Colburn j factors.<br>*Application of a correction for mass transfer rate gives the* AP600 forced convection mass transfer correlation | - Gilliland and Sherwood evaporation tests<br>- Westinghouse STC flat plate evaporation tests<br>- University of Wisconsin condensation tests | Complete.<br>NTD-NRC-95-4397<br>"Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus"<br><br>~~Complete.~~<br>WCAP-14326 gives correlation (§2.0, 2.1), entrance effect used for separate effect test (§2.2), and correlation validation with tests (§3.6, 3.7). | AP600 shown to operate in forced convection dominant regime.<br><br>Correlation is biased 6.4% conservative with reasonable scatter over the range<br>~~μ = 0.936~~<br>~~σ = 0.138~~<br><br>*Once the outer shell heats up to at least 2F above ambient, the AP600 annulus operates in forced convection.* | ~~LST covers range of AP600 Gr/Re2, including tests without the fan running~~<br><br>*LST includes tests with and without fan on, covering the annulus from mixed convection through forced convection dominated regimes.*<br><br>WCAP-14382<br>~~LST includes tests which cover range of AP600 subcooling.~~<br>Predictions of total evaporation (p. 8-3) and wall heat flux (p. 8-6) validate models in an integral setting. | WCAP-14382 summarizes WGOTHIC separate effects validation results (§3.2.1, 4.4) | Forced convection correlation, modified for mixed convection effects *to allow transient startup*, is appropriate for AP600.<br><br>*A conservative bias of 0.83 times the nominal correlation is used.*<br><br>~~Nominal correlation (with inherent conservative bias) used in WGOTHIC.~~ | ~~Included in code uncertainty~~<br><br>~~Uncertainty (scatter) is incorporated as an element of code uncertainty.~~<br><br>*Bounded* |

| PIRT Phenomenon | Ranking for Riser[1] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusions | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|---|---|---|---|---|
| **III. Module Solids** | | | | | | | | | |
| A. 1D transient conduction heat transfer | H | GOTHIC conductors used to model a few external concrete heat sinks, using the GOTHIC 1D conduction solution | CVTR | NTD-NRC-94-4260 "GOTHIC Containment Analysis Package, Version 3.4e, Volumes I-III," Volume 1, §6 describes the 1D conduction solution used.<br><br>WCAP-14382 provides validation with LST | Use of Uchida for heat sinks is conservative and consistent with SRP guidelines. | Not applicable | GOTHIC Qualification Report shows validation for the GOTHIC 1D conductor. | Conservatively bounded material properties are used for AP600 external conductors<br><br>Surface area and volume of heat sinks are conservatively underestimated. | Bounded |
| **IV. Inter-Module** | | | | | | | | | |
| A. Convection | M | Governing equations for lumped parameter volumes connected with junctions | LST without the fan operating validate ability to calculate natural convective flows | External flow rate and ΔT comparisons between WGOTHIC and LST have been presented at several meetings. These will be provided in a letter report.<br><br>*NTD-NRC-94-4085*<br>Sensitivities to external Kloss, both uniform and non-uniform, as well as sensitivity to air inlet blockages up to 50% were provided at the March 17, 1994 NRC PCS meeting.<br><br>As part of the Applications report, these sensitivities will be confirmed with evaluated using the final Evaluation Model. | For tests without the fan operating, external flow rate and ΔT is predicted well.<br><br>Pressure response is relatively insensitive to loss coefficient, since the system is self-correcting. The highly non-linear relation of evaporation rate with surface temperature results in increased evaporative cooling with only moderate surface temperature increases. | LST without the fan operating are applicable for validation of natural convective flows through the annulus with the 1D annulus flow model. | For tests without the fan operating, external flow rate and ΔT is predicted well. | A 1D lumped parameter model is used with an input nominal loss coefficient in WGOTHIC analyses.<br><br>Buoyancy driven flows are balanced by the form and friction losses. | Negligible effect due to weak sensitivity to external Kloss |
| B. Conduction | H | Climes include 1D conduction model used for conduction through containment shell | Comparison to theoretical solutions | Complete.<br>WCAP-14382 §2.5 shows the governing equation and discretization for 1D conduction, as well as model validation. | The 1D conduction model is correctly programmed into WGOTHIC | 1D conduction used to model heat transfer through the LST shell, which neglects the additional heat removal by azimuthal conduction from dry to wet surfaces. | WCAP-14382, §4.1 contains validation of the 1D conduction equations used in Climе subroutines. | 1D conduction equation is part of the Clime subroutines used for heat transfer through the shell.<br><br>Using 1D conduction conservatively neglects azimuthal conduction from dry to wet stripes.<br><br>Conservative material properties are used.<br><br>Effects of degradation corrosion of inorganic zinc paint are included in material properties. | Conservatively bounded material properties are used for AP600 containment shell. |

| PIRT Phenomenon | Ranking for Riser[1] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusions | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|---|---|---|---|---|
| C. Form and friction losses | H | External flow path hydraulic resistance | Air flow path ΔP test, ~1/6 scale | Complete<br>~~See also the blocks on Items I.C and IV.A.~~<br>*See also the line addressing Item I.C.*<br>*"External flow path is a 1D hydraulic model."*<br><br>*NTD-NRC-94-4083*<br>*Sensitivities to external Kloss, both uniform and non-uniform, as well as sensitivity to air inlet blockages up to 50% were provided at the March 17, 1994 NRC PCS meeting.* | Loss coefficient for external flow path | | LST - used constant loss coefficient for all predictions | Nominal loss coefficient used; lack of sensitivity | Negligible effect due to weak sensitivity to external Kloss |

**Table 1: PIRT Application to Evaluat**

| Module | PIRT Phenomena | Ranking for Containment | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NR |
|---|---|---|---|---|---|
| I. Volume | A. Multi-component Compressible Gasses | H | Gas constituents in the governing equations | All tests analyzed with WGOTHIC | Complete<br>NTD-NRC-94-4260<br>Enclosure 1: GOTHIC Technical Manual describe governing equations<br>Enclosure 2: GOTHIC User's Manual describes how to invoke various gasses<br>Enclosure 3: GOTHIC Qualification Report provides large database of tests with air, hydrogen, and helium<br>NTD-NRC-95-4462<br>EPRI Report RA-93-10, GOTHIC Design Review, Final Report<br>WCAP-14382 validates WGOTHIC with separate effects, integral tests with steam *and* air, ~~and helium~~ |
| | B. Buoyancy | H | Buoyancy forces are included in the lumped parameter junction governing equations | LST *internal boouyant flows*<br>~~Hugot tests~~<br>~~Siegel & Norris tests~~ | Complete<br>*WCAP-14326, Separate effects test*<br>WCAP-14382, *for integral tests* |

**Model: Inside Containment - All phases**

| Report Conclusions | Applicability of LST with Respect to Phenomena | Validation of Modeling Method and/or WGOTHIC | Use of Validation Results in this Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|
| Effects of multicomponent compressible gasses are correctly included in governing equations | LST includes air *and* steam, ~~and helium~~ | WGOTHIC has been validated with the LST | Governing equations in WGOTHIC are a valid representation of compressible, multicomponent gas behavior<br>Maximum Technical Specification pressure used in conjunction with 0% relative humidity. | Bounded |
| Lumped modeling overmixes noncondensibles above operating deck thereby reducing heat removal from vessel when PCS is dominant<br>Distributed parameter modeling shows good agreement with 550 node LST model.<br>Modeling of buoyancy and entrainment is acceptable. | Steam injection point elevation and direction effects tests were performed<br>LST has prototypical buoyancy driving forces and covered the range of Froude numbers for LOCA | WGOTHIC has been validated with the LST | ~~Mixing and stratification resulting from buoyancy driven flow will be studied in the WGOTHIC Applications WCAP~~<br>*See boxes for line IV.A.* | ~~Sensitivity to mixing will be provided in applications WCAP~~<br>*Bounded* |

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Table 1: PIRT Application to Evaluat

| Module | PIRT Phenomena | Ranking for Containment | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NR |
|---|---|---|---|---|---|
| | C. Flow Field Stability or Stratification | L | Mixing within the containment upper regions and mixing between the upper and lower portions of the containment | LST | NTD-NRC-95-4459, Stratification and Mixing Effects on AP600 Passive Containment Cooling System DBA WGOTHIC Applications Document ACRS T/H Subcommittee Meeting, March 29-30, 1995 (to be documented in letter report) |
| | | | | | |
| II. Surface | A. Liquid Film Heat Transfer | M | Thermal conductivity of liquid film for film temperature drop | Chun & Seban Wisconsin Condensation Tests | Complete NTD-NRC-94-4100, Enclosure 2 "Liquid Film Model Validations" WCAP-14382 §2 |
| | B. Liquid Film Stability/Coverage | L | Condensation on the interior surface of containment | LST Wisconsin Condensation Tests | WCAP-13307 I.K. Huhtininemi, "Condensation in the Presence of Noncondensib Gas: Effect of Surface Orientation," Ph.D. Thesis Univ. Wisconsin, 1992 |
| | C. Liquid Film Enthalpy Transport | M | Liquid film energy conservation equation | LST Wisconsin Condensation Tests | Complete WCAP-14382 §2.4, 2.5 show equations for liquid film WCAP-14190 |

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## on Model: Inside Containment - All phases

| Report Conclusions | Applicability of LST with Respect to Phenomena | Validation of Modeling Method and/or WGOTHIC | Use of Validation Results in this Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|
| Blowdown is the same as standard plants. Long-term LOCA is driven by buoyant plume and LST covers range for AP600. MSLB is well mixed due to high velocity jet. Distributed parameter modeling shows good agreement with 550 node LST model. Modeling of buoyancy and entrainment is acceptable. | Upper and lower regions of containment represented in the LST | WGOTHIC model has been validated with the LST | ~~Mixing and stratification resulting from buoyancy driven flow will be studied in the WGOTHIC Applications WCAP~~ *See boxes for line IV.A* | ~~Sensitivity to mixing and break size will be provided in applications WCAP~~ *Bounded* |
| | | | | |
| The Chun and Seban data provides a basis for film thermal conductivity. | Internal and external liquid film effects are represented in the LST | All validation performed with WGOTHIC includes the small effect of film temperature drop | Nominal wavy-laminar and turbulent Chun and Seban correlations used as appropriate | Negligible effect since resistance across film is small part of total resistance |
| Internal films are stable since containment shell slope is in excess of 1°. Droplet formation improves mass transfer | Prototypical surfaces included in the LST Separate effects studied in Wisconsin Condensation Tests | WGOTHIC model has been validated with the LST | Shell slopes modeled with WGOTHIC exceed 1° Condensate on containment is returned to the IRWST Benefits of droplet formation neglected | Bounded |
| Subcooling is negligible compared to energy transported to liquid field | Prototypical surfaces included in the LST Separate effects studied in Wisconsin Condensation Tests | WGOTHIC model has been validated via the LST and Wisconsin Condensation Tests | Temperature profile through film considered in solution | Negligible, film is at or near saturation temperature |

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9509060132-02

## Table 1: PIRT Application to Evaluat

| Module | PIRT Phenomena | Ranking for Containment | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NR |
|---|---|---|---|---|---|
| | D. Free Convection Heat Transfer | L | McAdams Flat Plate Correlation ~~Mixed Convection~~ | LST | WCAP-14190 page 2-7<br>WCAP-14326 page 4-1<br>WCAP-14382 §8 |
| | E. Forced Convection Heat Transfer | L | ~~Lumped~~ - Not modeled ~~Distributed - flat plate forced convection, mixed convection~~ | LST | WCAP14190 page 2-7<br>WCAP-14326 page 4-1<br>WCAP-14382 §8 |
| | F. Radiation Heat Transfer | L | Not modeled | LST | WCAP-14190 page 2-8 |
| | G. Free Convection Mass Transfer | H | ~~Lumped~~ - Heat and mass transfer analogy based on McAdams flat plate heat transfer correlation ~~Distributed - Heat and mass transfer analogy using the mixed convection correlation~~ | LST Wisconsin Condensation Tests | WCAP-14190 page 2-8<br>WCAP-14326 §3.8, 3.9, 4.<br>WCAP-14382 §4.3, 8.2 |
| | H. Forced Convection Mass Transfer | L | ~~Lumped~~ - Not modeled ~~Distributed - Heat and mass transfer analogy based on flat plate forced convection in the mixed convection correlation~~ | LST *Wisconsin Condensation Tests* | WCAP-14190 page 2-8<br>WCAP-14326 §3.8 |
| | | | | | |

**on Model: Inside Containment - All phases**

| Report Conclusions | Applicability of LST with Respect to Phenomena | Validation of Modeling Method and/or WGOTHIC | Use of Validation Results in this Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|
| *Convective* heat transfer is not significant in comparison to mass transfer | Prototypical internals Range of validation defined in WCAP-14382 §9.2 | WGOTHIC model has been validated with the LST | *A conservative bias of 0.741 times the nominal correlation is used* | *Bounded by conservative bias* |
| Convective heat transfer is not significant in comparison to mass transfer | Prototypical internals Range of validation defined in WCAP-14382 §9.2 | WGOTHIC model has been validated with the LST | ~~Lumped~~ - Forced convection heat transfer not considered ~~Distributed - Nominal flat plate correlation~~ | ~~Lumped~~ - Bounded by neglecting forced convection ~~Distributed - Bounded by code uncertainty~~ |
| Temperature differences within containment are small enough that radiative heat transfer is low | Prototypical internals and temperature driving forces modeled in LST | WGOTHIC modeling of LST neglected radiative heat transfer | Not modeled | Bounded |
| Mass transfer conservatively biased mean=0.983 σ=0.187 | Prototypical internals and temperature driving forces modeled in LST Range of validation defined in WCAP-14382 §9.2 | LST internal data as a separate effect Wisconsin Condensation Tests | *A conservative bias of 0.741 times the nominal correlation is used* | *Bounded by conservative bias* |
| Mass transfer conservatively biased mean=0.968 σ=0.203 | Prototypical internals and Froude numbers modeled in LST Range of validation defined in WCAP-14382 §9.2 | ~~Lumped~~ - Validated WCAP-14382 §8 Dominant only during first sec[illegible] of *LOCA* transient ~~Di[illegible]ed - Dominant only during first seconds of transient~~ | ~~Lumped~~ - Not modeled ~~Distributed - Mixed convection correlation combining free and forced convection with a conservative bias~~ | *Bounded by neglecting forced convection* |
| | | | | |

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9509060132-03

Table 1: PIRT Application to Evalua

| Module | PIRT Phenomena | Ranking for Containment | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NR |
|---|---|---|---|---|---|
| III. Solids | A. 1-D Transient Conduction Heat Transfer | H | GOTHIC conductors used to model internal heat sinks include a 1-D conduction solution | CVTR<br>LST with internal heat sinks | NTD-NRC-94-4260 "GOTHIC Containment Analysis Package, Version 3.4e, Volumes 1-111," Volume 1, §6 describes the 1-D conduction solution used.<br>WCAP-14382 provides validation with LST |
| | | | | | |

on Model: Inside Containment - All phases

| | Report Conclusions | Applicability of LST with Respect to Phenomena | Validation of Modeling Method and/or WGOTHIC | Use of Validation Results in this Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|---|
| | Use of Uchida with 1-D conductor for internal heat sinks is conservative and consistent with SRP guidelines | Internal LST heat sinks are modeled using GOTHIC conductors with Uchida for condensation | WCAP-14382 shows validation results with internal heat sinks modeled with Uchida | SRP guidelines are an acceptable approach. Conservatively bounded material properties are used for AP600 internal conductors. Surface area and volume of internal heat sinks are conservatively underestimated. | Bounded |
| | | | | | |

Table 1: PIRT Application to Evaluat

| Module | PIRT Phenomena | Ranking for Containment | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NR |
|---|---|---|---|---|---|
| IV. Inter-Module | A. Convection | L | Governing equations for lumped parameter volumes connected with junctions and node-to-node connections for distributed parameter | LST | NTD-NRC-95-4459, Stratification and Mixing Effects on AP600 Passive Containment Cooling System DBA<br>WCAP-14382 §5.3<br>WGOTHIC Applications Document<br>WCAP-14190 §9 |

**a Model: Inside Containment - All phases**

| Report Conclusions | Applicability of LST with Respect to Phenomena | Validation of Modeling Method and/or WGOTHIC | Use of Validation Results in this Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|
| *Fr scaling shows MSLB expected to be well mixed. Flow area restriction in evaluation model limits steam access to below deck during short MSLB releases*<br>Lumped - Overmixing penalizes heat and mass transfer when PCS is dominant *(LOCA longterm)*<br>Distributed - 375 node LST ~~is sufficiently accurate with~~ *has* slight bias towards overmixing - can bias mixing with flow areas<br>*LOCA blowdown pressurizes SG compartment sufficiently to drive flow throughout lower compartments. Natural circulation develops post-blowdown* | Applicable to above deck circulation and heat and mass transfer correlation validation<br>*LST has been used to develop rationale for bounding approach on mixing* | *Mixing biased toward worst case for each accident.*<br>*A sensitivity using nominal flow area in the AP600 will be provided in the Applications WCAP to quantify conservative bias.* | Restrict mixing between upper and lower regions of containment when mixing is a benefit *(LOCA second peak)* | Bounded *by biasing mixing in conservative direction for each accident* |

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Table 1: PIRT Application to Evaluat

| Module | PIRT Phenomena | Ranking for Containment | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NR |
|---|---|---|---|---|---|
| | B. Conduction | H | Climes include 1-D conduction model used for conduction through containment shell | Comparison to theoretical solutions | Complete. WCAP-14382 §2.5 shows the governing equation and discretization for 1-D conduction |
| | C. Form and Friction Losses | L | Inter-compartment losses | Standard experimentally based loss coefficients | *WCAP-14382 §6.0 describes methods used to model LST* |

n Model: Inside Containment - All phases

| Report Conclusions | Applicability of LST with Respect to Phenomena | Validation of Modeling Method and/or WGOTHIC | Use of Validation Results in this Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|
| The 1-D conduction model is correctly programmed into WGOTHIC | 1-D conduction used to model heat transfer through the LST shell, which neglects the additional heat removal by azimuthal conduction from dry to wet surfaces. | WCAP-14382 §4.1 contains validation of the 1-D conduction equations in Clime subroutine | 1-D conduction equation is part of the Clime subroutines used for heat transfer through the shell. Effects of degradation of inorganic zinc paint are included in material properties. Conservative material properties used. Using 1-D conduction conservatively neglects azimuthal conduction from dry to wet stripes. | Bounded |
| *Use of standard loss coefficients through grating is validated* | *Simplified representation of lower compartments* | *See IV.A.* | Restrict mixing between upper and lower regions of containment when mixing is a benefit. *Increase mixing when it is a penalty. (See IV.A.)* | *Bound effects of mixing.* |

## Table 2: PIRT Application to Evaluation Model: Outside Containment - LOCA - All Phases

| PIRT Phenomenon | Ranking for ~~Riser~~[(1)] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclus |
|---|---|---|---|---|---|
| **I. Module Volume** | | | | | |
| A. Multi-component compressible gasses | H | Gas constituents in the governing equations | All tests analyzed with WGOTHIC | Complete<br>NTD-NRC-94-4260<br>Enclosure 1: GOTHIC Technical Manual* describes the governing equations<br>Enclosure 2: GOTHIC User's Manual describes how to invoke various gasses<br>Enclosure 3: GOTHIC Qualification Report provides a large database of tests with air, hydrogen, and helium.<br><br>NTD-NRC-95-4462<br>EPRI Report RA-93-10, GOTHIC Design Review, Final Report<br><br>WCAP-14382 validates WGOTHIC with separate effects and integral tests with steam, air, and helium gases.<br><br>~~*Revision will be made to correct typographical errors.~~<br><br>**Westinghouse will expedite revised documentation which addresses Peer Review results.* | Effects of multi- component com gasses are cor included in gov equations. |
| B. Buoyancy | H | Buoyancy forces are included in the lumped parameter - junction governing equations | • LST without fan running<br>• Hugot tests<br>~~• Eckert and Diaguila tests~~<br>• Siegel and Norris tests | Complete<br>WCAP-14382 §7.2.2 identifies the relevant priority ~~test~~ *LST* with fan off to support external annulus modelling.<br><br>*WCAP-14326 § 3.1, 3.3*<br><br>*NTD-NRC-94-4083*<br>*W/NRC PCS Meeting*<br><br>~~To be issued:~~ *As part of the* Applications Report, ~~Document~~ the sensitivity to Kloss (uniform and nonuniform) and nominal delay time *will be confirmed using the final evaluation model.* | The external a predictions pro *comparisons to* ~~reasonable agr~~ ~~with~~ LST ~~and a~~ ~~uncertainties c~~ ~~accommodated~~ ~~DBA.~~<br><br>*External separ with buoyancy flows are valid*<br><br>*Weak sensitivi (uniform and n has been show* |

Date last modified: August 28, 1995



| s | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|
| | | | | |
| essible<br>lly<br>ing | LST includes air, steam, and helium. | WCAP-14382 provides validation of external annulus modelling methods. | Governing equations in WGOTHIC are a valid representation of compressible, multi-component gas behavior.<br><br>*Maximum Tech Spec value of environment temperature is used as the boundary condition in WGOTHIC models.* | ~~Included in code uncertainty~~<br><br>*Bounded* |
| ulus<br>e<br><br>~~ment~~<br>~~ociated~~<br>~~be~~<br>~~the~~<br><br>*effects*<br>*iven*<br>*d.*<br><br>*to Kloss*<br>*uniform)* | ~~All~~ *7 baseline and 7 confirmatory* LST in the HWRF program were run with the fan off.<br><br>The LST priority test 214.1 *(fan off)* has been used for validation. | WGOTHIC has been validated with LST *214.1* with natural convection driving the annulus flows in WCAP-14382 §5, 6, 7, 8. | The external annulus is modelled with pressure boundary conditions at the inlet and outlet, such that the imposed ΔP is ≤ ~~equal to~~ the external density head *driving force. Thus,* the initial annulus air flow is conservatively established at a *slightly* negative value *(directed downward in the annulus).*<br><br>The momentum equation is solved, balancing the buoyancy driving head with the unrecoverable losses through the annulus. | Nominal loss coefficient is used.<br><br>Weak sensitivity to loss coefficient.<br><br>Conservative initial air flow bounds postulated annulus flow start-up concerns. |

| PIRT Phenomenon | Ranking for ~~Riser~~[1] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclus |
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| C. Flow field stability or stratification | L | External flow path is a 1D hydraulic model | • *LST riser*<br>• *External flow path ΔP test*<br>• *Eckert and Diaguila*<br>• *Siegel and Norris*<br>• *Hugot* | Complete<br>NTD-NRC-95-*4414*<br>RAI 952.102 response:<br>WCAP-14190, Section 7.2 and 7.3 provide momentum and energy scaling for justification.<br><br>WCAP-14382, §8 provides validation using 1D flow path for annulus.<br><br>~~To be issued: Applications Report Document sensitivity to Kloss (uniform and nonuniform) and nominal delay time.~~<br>*See block on line above for loss coefficient study results.* | Potential for loc recirculation *at downcomer inle* total air flow at operating condi negligible *since minimal energy momentum in th downcomer.*<br><br>Small sensitivity large Kloss effe |
| | - | Fog in annulus | - | Complete<br>NTD-NRC-94-4100, Enclosure 1<br>"Radiation Heat Transfer Through Fog in the PCCS Air Gap" | Justification for effect of fog in since effect of r capture by fog has a negligible the annulus air temperature an overestimates t transfer to the b |
| | - | Effect of wind-induced recirculation and stratified atmosphere is neglected | Literature | Complete<br>NTD-NRC-94-4166<br>"AP600 Containment Plume Investigation" | Quantification o for recirculation and thermally s atmosphere to cooling rates ga bounding recirc fraction, and a sensitivity show significant conta pressure effect |
| | | Effect of wind-induced turbulence is neglected | Wind tunnel tests | Complete.<br>NTD-NRC-95-4467<br>"Analysis of AP600 Wind Tunnel Testing for PCS Heat Removal" | Oscillating flows case site with le positive mean w coefficient sligh increase heat re rates from cont Less severe ter more positive w coefficients sho significant incre heat removal. |

| s | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
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| o affect<br>600<br>ns is<br>ere is<br><br>fairly<br>s | ~~N/A~~<br><br>*Successful modelling of the external annulus with a 1D flow path shows ability of 1D model to predict riser phenomena.* | *The downcomer flow area is large to act as a reservoir within which pressures can equalize, providing a relatively uniform inlet for the annulus.* ~~Use of 1D flow path is justifiable~~ Since heat transfer and momentum in the downcomer, relative to the riser, is so small ~~that~~ the possibility of downcomer instabilities is insignificant. *Flow is primarily one-dimensional in nature; therefore, use of 1D flow path is justifiable.*<br><br>*Since fully developed turbulent flow develops in annulus before the baffle heats up, there is no potential for hot-baffle-induced flow instability to impact* ~~impact on~~ start-up of annulus air flow. | External flow path is modelled as 1D lumped parameter | Negligible effect<br><br>Weak sensitivity to *external* loss coefficient *shows pressure is not sensitive to postulated inhibitors to external flow.* |
| glecting<br>nulus<br>liation<br>AP600<br>ffect on<br><br>heat<br>ffle. | Database consistent with AP600 expectations *for external annulus conditions.* | Effect of fog neglected in WGOTHIC models | Negligible effect on answers | Negligible effect |
| otential<br>f effluent<br>tified<br>ect<br>e<br>ation<br>sulting<br>d no<br>ment | LST was run in no-wind (<5 mph) conditions | External pressure boundary condition is unadjusted for these effects | Assumption of no recirculation due to these effects has negligible impact on pressure prediction | Negligible effect |
| or worst<br>st<br>nd<br><br>noval<br>nment.<br>ins with<br>d<br><br>es in | Not applicable | External pressure boundary condition is unadjusted for these effects | Assumption of no wind is bounding for pressure prediction | Bounded |

| PIRT Phenomenon | Ranking for ~~Riser~~[(1)] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusi |
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| **II. Module Surface** | | | | | |
| A. Liquid film heat transfer | M | Thermal conductivity of liquid film for film temperature drop. | Chun and Seban | Complete<br>NTD-NRC-94-4100, Enclosure 2<br>"Liquid Film Model Validation"<br><br>WCAP-14382 §2<br><br>~~Scaling supplement will document consistent definition of resistances inside to outside shell~~ | The Chun and S<br>data provides a<br>film thermal con<br><br>The liquid film<br>temperature dro |
| B. Liquid film stability/coverage | H | Shell water coverage fractions *and applied flow rate* | • Full scale, cold 1/8 sector tests<br><br>• Hot LST measured coverage<br><br>*• Westinghouse flat plate evaporation tests*<br><br>• Vendor age/contamination *information* ~~tests~~ | Complete.<br><br>*WCAP-12665, §3.1*<br><br>NTD-NRC-94-4247<br>"Method for Determining Film Flow Coverage for the AP60؛ Passive Containment Cooling System"<br><br>NTD-NRC-94-4286<br>"Supplemental Information on AP600 PCS Film Flow Coverage Methodology," *including sensitivity to 3/4 and 1/2 of bounding SSAR coverages showing well away from any cliffs in performance.*<br><br>*SSAR Rev. 4 Preliminary Markup 6.2.1.1.3 summarizes water coverage assumptions.*<br><br>*NTD-NRC-94-4083*<br>*W/NRC PCS Meeting*<br>*Weak sensitivity to PCS flow rate, water coverage fraction, PCS time delay was shown.*<br><br>~~To be issued:~~<br>~~Vendor report on effects of age and contamination.~~<br><br>~~Note: An independent review by an industry expert is also planned.~~ | *Tests with wate*<br>*surfaces up to 2*<br>*showed that the*<br>*without delay, e*<br>*quenching a ho*<br>*cold water. Eva*<br>*films do not bec*<br>*unstable, even*<br>*film dryout.*<br><br>Water coverage<br>and sidewalls a<br>function of time<br>bound (Figure 2<br>scale data and<br>data from LST.<br>model has been<br>with cold and h<br>tests, and boun<br>data.<br><br>Model ~~adequate~~<br>conservatively a<br>for effects of ag<br>*using a* ~~via its e~~<br>~~the~~ wetting angl<br>*new surface.* A<br>increases the p<br>the surface and<br>increases wettir<br>Surface contam<br>be minimal bas<br>inspection and<br>criteria. Sensiti<br>using *approxim*<br>*and* 1/2 ~~and ¼~~<br>bounding SSAR<br>values show tha<br>AP600 pressure<br>is relatively inse<br>further reductio<br>coverage below<br>bounding minim<br>evaluation mod |

| | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
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| an sis for tivity. small. | Internal and external liquid film effects are represented in the LST. | All validation performed with WGOTHIC includes the small effect of film temperature drop. | Nominal Chun and Seban correlation is used, accounting for wavy laminar and turbulent liquid films. | Negligible effect since resistance across film is small part of total resistance. |
| *nto F ate wet ate with rating e total* dome used to old, full ated e alidated ed test ounts *by* ~~st on~~ *for a* g rity of us nts will on aning es *ly 3/4* overage he esponse itive to in e n values. | Heated LST data has been used to assess heat flux effect on coverage fraction.<br><br>Measured coverage fractions on the LST were used as input boundary conditions in the WGOTHIC validation runs to validate cooling rate prediction models with test data. | Water coverage is an input boundary condition *to the WGOTHIC code. A "top-to-bottom stack" of climes is used to model each of the wetted and dry portions of the external shell. Coverage fractions are used to determine the maximum value of potentially wetted shell heat transfer surface area input to the WGOTHIC climes model. Coverage for the dome at top and mid levels is assumed to be 40% to bound full scale cold test data, where the film is thick enough that film stability does not limit coverage.*<br><br>*The wetted cross sectional area of the balance of the wetted portion where film stability limits coverage is obtained from 26.17 hrs in Table 4 of NTD-NRC-94-4247, where 100% dome coverage values show that film stability does not limit dome coverage. The Table 4 values have not been adjusted to account for the reduced evaporation associated with the assumed 40% coverage on the dome. Therefore, the coverage fraction assumed in the DBA bounds all times during the PCS DBA.*<br><br>*Weak sensitivity to the input water coverage shows that minor perturbations in this assumption do not impact pressure predictions.* | The validated conservative water coverage model is used to calculate input boundary conditions for the PCS DBA Evaluation Model.<br><br>Bounding minimum water coverage fractions *are* used | Bounded |

| PIRT Phenomenon | Ranking for ~~Riser~~(1) External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclu |
|---|---|---|---|---|---|
| | | Shell wetting time delay | • Full scale, cold 1/8 sector tests | *NTD-NRC-94-4083*<br>*W/NRC PCS Meeting*<br><br>~~A written~~ *The* discussion *in the boxes to the right* will be provided in the applications report. | *Weak sensitivi flow rate, wate fraction, PCS was shown.* |
| C. Liquid film subcooling | M | Liquid film energy conservation equation | Large Scale Tests | Complete<br>WCAP-14382 §2.4, 2.5 show equations for liquid film | Inclusion of co term in energy accounts for li subcooling eff dome heat flu |
| D. Free convection heat transfer | L | Mixed convection correlation which reduces to the McAdams correlation, at high $Gr/Re^{2.7}$, with characteristic length in Gr number based on channel diameter | • Hugot tests<br>• Eckert and Diaguila tests<br>• Siegel and Norris tests<br>• Westinghouse LST - dry external heat transfer | Complete<br>WCAP-14190<br>Quantifies AP600 fraction of heat removed by convective heat transfer.<br><br>NTD-NRC-95-4397<br>Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus<br><br>*WCAP-14326 separate effects tests validation* | *Free* convecti transfer *can b in the AP600* ~~accounts for a fraction of tota transferred.~~<br><br>~~See also force convection he~~<br><br>*The mixed co correlation pre data with a co mean bias of* |

| s | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
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| *PCS verage delay* | LST 219.1 has water onto hot surface and thermocouple temperatures show the surface readily rewets during the high flow portion of the non-prototypical oscillating flow.<br><br>Videotapes of a shakedown LST with a somewhat higher flow rate show water behavior applied to 240F surface. The observations showed that the advancing film front sizzled as it was boiled away, and readily flowed down as wide stripes after the surface fell below the leidenfrost temperature. | Input Boundary Condition delay time produces a conservative result.<br><br>Earlier water application does not adversely impact air flow initiation because there ~~is~~ *would be* a net improvement ~~in~~ *due to* evaporative cooling.<br><br>The effect on annulus air temperature and vapor content of water applied to the surface is explicitly modeled in WGOTHIC 1D annulus calculation. A sensitivity based on actual chronology with earlier wetting will be provided in the Applications report. | Since the outer surface *temperature does not increase significantly* ~~is not hot~~ until after water reaches *the containment shell* surface in real time, cold tests are acceptable to determine delay times. Delay time to wet the external surface is conservatively bounded by using time to reach steady state coverage fractions from the cold full scale test. This conservative delay time thus neglects *integrated* heat removal during about *10* ~~5~~ minutes of actual water application *during the period when steady state film coverage is developing.* ~~when surface temperature has not significantly increased.~~<br><br>Time delay used bounds all postulated effects | Bounded |
| ctive uation film on LST | LST covers range of liquid film subcooling expected for AP600.<br><br>Although a majority of the LST have higher fractions of energy removed by subcooling than AP600, the LST is valid for *developing a bounding approach for AP600* ~~validation of~~ physics and phenomena since a scalable liquid film enthalpy transport model is used. | WCAP-14382, p. 8-6 discusses validation of LST heat flux distribution predictions over the dome. | WGOTHIC uses an appropriate set of governing equations for liquid film. Subcooling accounts for a small fraction (~5%) of the AP600 heat removal. | Negligible effect since mechanism accounts for only small fraction of AP600 heat removal. |
| heat *eglected r.* ~~hall~~ ~~eat~~ ~~ransfer~~ *ction ts the ervative %.* | *Once the outer shell heats up to at least 2F above ambient, the AP600 annulus operates in forced convection.*<br><br>LST ~~includes~~ tests with and without fan on, cover~~ing~~ the annulus from *mixed* ~~free~~ convection through forced convection dominated regimes. | Mixed convection correlation provides good agreement with annulus conditions in the LST. | Mixed convection correlation reduces to forced convection at ~~high~~ *low* $Gr/Re^{2.7}$, consistent with expectation for AP600 annulus conditions.<br><br>*A conservative bias of 0.83 times the nominal correlation is used.* | ~~Negligible effect~~<br><br>*Bounded* |



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| PIRT Phenomenon | Ranking for ~~Riser~~(1) External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclus |
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| E. Forced convection heat transfer | L | Mixed convection correlation which reduces to the Colburn correlation at low $Gr/Re^{2.7}$ | • Hugot tests<br>• Eckert and Diaguila tests<br>• Siegel and Norris tests<br>• Westinghouse STC dry flat plate tests<br>• Westinghouse LST - dry external heat transfer | Complete<br>WCAP-14190<br>Quantifies AP600 fraction of heat removed by convective heat transfer.<br><br>WCAP-14326, §3.1, 3.2, 3.3, 3.4, 3.5, and 4.1 shows validation of the correlations with separate effects tests | *Forced* convec<br>transfer *domin*<br>*AP600 riser.* a<br>~~a small fraction~~<br>~~heat transferre~~<br><br>*The mixed co*<br>correlation is b<br>conservative a<br>mean over the<br>a relatively lar<br>due to large m<br>uncertainty wit<br>~~$\mu = 0.976$~~<br>~~$\sigma = 0.278$~~ |
| F. Radiation heat transfer | L | Wall-to-wall radiant heat transfer | • Westinghouse STC dry flat plate tests<br>• Dry LST | Complete<br>WCAP-14382, §2.5 describes the radiant heat transfer model used in Climes | Dry external v<br>transfer is vali |
| G. Free convection mass transfer | - | Empirical correlation for the Sherwood number, which is derived by dimensional analysis using the Reynold's analogy and Colburn j factors. | • Gilliland and Sherwood evaporation tests<br>• Westinghouse STC flat plate evaporation tests<br>• University of Wisconsin condensation tests | Complete<br>~~See free convection heat transfer~~<br><br>*NTD-NRC-95-4397*<br>*Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus*<br><br>*WCAP-14326 separate effects tests validation* | ~~See free conve~~<br>~~transfer~~<br><br>*The annulus is*<br>*by forced conv*<br>*mass transfer*<br>*outer shell hea*<br>*least 2F above*<br>*during the tran* |
| H. Forced convection mass transfer | H | Empirical correlation for the Sherwood number, which is derived by dimensional analysis using the Reynold's analogy and Colburn j factors.<br>*Application of a correction for mass transfer rate gives the* AP600 forced convection mass transfer correlation | • Gilliland and Sherwood evaporation tests<br>• Westinghouse STC flat plate evaporation tests<br>• University of Wisconsin condensation tests | Complete.<br>NTD-NRC-95-4397<br>"Supporting Information for the Use of Forced Convection in the AP600 PCS Annulus"<br><br>~~Complete.~~<br>WCAP-14326 gives correlation (§2.0, 2.1), entrance effect used for separate effect test (§2.2), and correlation validation with tests (§3.6, 3.7). | AP600 shown<br>in forced conv<br>dominant regi<br><br>Correlation is<br>conservative w<br>reasonable sc<br>the range.<br>~~$\mu = 0.936$~~<br>~~$\sigma = 0.139$~~<br><br>*Once the oute*<br>*up to at least*<br>*ambient, the A*<br>*annulus opera*<br>*forced convec* |

| | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
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| heat *in* ~~nts for otal~~ *ion d 2.4% the ge, with catter rement all ΔT.* | Dry LST has dominant annulus heat removal by convection<br>*The LST and separate effects tests cover the range of AP600 Reynold's numbers.* | WCAP-14382, §3.2.1, 4.2 provide summaries of the validation.<br>Although the comparisons with data show high scatter, it is attributable to high instrument uncertainty with small ΔT. The lack of any trend in the mean over the range indicates the correlation is reasonable as a basis for mass transfer analogy. Mass transfer validation, covering ΔT an order of magnitude higher, shows much less scatter. | ~~Nominal correlation (with inherent conservative bias) used in WGOTHIC.~~<br>*A conservative bias of 0.83 times the nominal correlation is used.*<br>Convective heat transfer is not a dominant ~~significant~~ heat removal mechanism for AP600 DBA. | ~~Uncertainty (scatter) is incorporated as an element of code uncertainty.~~<br>*Bounded* |
| heat d. | Varying fractions of dry shell surface are included for all wet tests. The dry LST cases transfer a large fraction of heat by radiation to the baffle. | WCAP-14382 §7 shows selection of LST and §8 shows validation results. | Conservative property values are used in AP600 DBA. | Bounded |
| ~~n heat~~ *minated on e the p to at bient t.* | ~~See free convection heat transfer~~<br>*LST includes tests with and without fan on, covering the annulus from mixed convection through forced convection dominated regimes.* | ~~See free convection heat transfer~~<br>*WCAP-14382 summarizes WGOTHIC separate effects validation results (§3.2.1, 4.4)* | ~~See free convection heat transfer~~<br>*A conservative bias of 0.83 times the nominal correlation is used.* | ~~Negligible effect~~<br>*Bounded* |
| perate n *ed 6.4% over ell heats bove 00 in* | ~~LST covers range of AP600 Gr/Re2, including tests without the fan running~~<br>*LST includes tests with and without fan on, covering the annulus from mixed convection through forced convection dominated regimes.*<br>WCAP-14382<br>~~LST includes tests which cover range of AP600 subcooling;~~ Predictions of total evaporation (p. 8-3) and wall heat flux (p. 8-6) validate models in an integral setting. | WCAP-14382 summarizes WGOTHIC separate effects validation results (§3.2.1, 4.4) | Forced convection correlation, modified for mixed convection effects *to allow transient startup*, is appropriate for AP600.<br>*A conservative bias of 0.83 times the nominal correlation is used.*<br>~~Nominal correlation (with inherent conservative bias) used in WGOTHIC.~~ | ~~Included in code uncertainty~~<br>~~Uncertainty (scatter) is incorporated as an element of code uncertainty.~~<br>*Bounded* |



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| PIRT Phenomenon | Ranking for ~~Riser~~[(1)] External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclus |
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| **III. Module Solids** | | | | | |
| A. 1D transient conduction heat transfer | H | GOTHIC conductors used to model a few external concrete heat sinks, using the GOTHIC 1D conduction solution | CVTR | NTD-NRC-94-4260<br>"GOTHIC Containment Analysis Package, Version 3.4e, Volumes I-III," Volume 1, §6 describes the 1D conduction solution used.<br><br>WCAP-14382 provides validation with LST | Use of Uchida f sinks is conserv consistent with guidelines. |
| **IV. Inter-Mod** | | | | | |
| A. Convection | M | Governing equations for lumped parameter volumes connected with junctions | LST without the fan operating validate ability to calculate natural convective flows | External flow rate and $\Delta T$ comparisons between WGOTHIC and LST have been presented at several meetings. These will be provided in a letter report.<br><br>*NTD-NRC-94-4083*<br>Sensitivities to external Kloss, both uniform and non-uniform, as well as sensitivity to air inlet blockages up to 50% were provided at the March 17, 1994 NRC PCS meeting.<br><br>As part of the Applications report, these sensitivities will be confirmed with ~~evaluated using~~ the final Evaluation Model. | For tests withou operating, exter rate and $\Delta T$ is well.<br><br>Pressure respo relatively insen loss coefficient system is self-c The highly non- relation of evap rate with surfac temperature re increased evap cooling with on moderate surfa temperature inc |
| B. Conduction | H | Climes include 1D conduction model used for conduction through containment shell | Comparison to theoretical solutions | Complete.<br>WCAP-14382 §2.5 shows the governing equation and discretization for 1D conduction, as well as model validation. | The 1D conduc is correctly pro into WGOTHIC |

| s | Applicabilit, of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
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| heat e and p | Not applicable | GOTHIC Qualification Report shows validation for the GOTHIC 1D conductor. | Conservatively bounded material properties are used for AP600 external conductors<br><br>Surface area and volume of heat sinks are conservatively underestimated. | Bounded |
| | | | | |
| he fan l flow dicted<br><br>is e to nce the ecting. ear tion<br><br>s in tive<br><br>ases. | LST without the fan operating are applicable for validation of natural convective flows through the annulus with the 1D annulus flow model. | For tests without the fan operating, external flow rate and ΔT is predicted well. | A 1D lumped parameter model is used with an input nominal loss coefficient in WGOTHIC analyses.<br><br>Buoyancy driven flows are balanced by the form and friction losses. | Negligible effect due to weak sensitivity to external Kloss |
| n model mmed | 1D conduction used to model heat transfer through the LST shell, which neglects the additional heat removal by azimuthal conduction from dry to wet surfaces. | WCAP-14382, §4.1 contains validation of the 1D conduction equations used in Clime subroutines. | 1D conduction equation is part of the Clime subroutines used for heat transfer through the shell.<br><br>Using 1D conduction conservatively neglects azimuthal conduction from dry to wet stripes.<br><br>Conservative material properties are used.<br><br>Effects of *degradation* ~~corrosion of~~ inorganic zinc paint are included in material properties. | Conservatively bounded material properties are used for AP600 containment shell. |

| PIRT Phenomenon | Ranking for ~~Riser~~(1) External Flow Path | AP600 BCs or Phenomena Models | Test Bases | Report Submitted to NRC | Report Conclusi |
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| C. Form and friction losses | H | External flow path hydraulic resistance | Air flow path ΔP test, ~1/6 scale | Complete<br>~~See also the blocks on items I.C and IV.A.~~<br>*See also the line addressing item I.C. "External flow path is a 1D hydraulic model."*<br><br>*NTD-NRC-94-4083*<br>*Sensitivities to external Kloss, both uniform and non-uniform, as well as sensitivity to air inlet blockages up to 50% were provided at the March 17, 1994 NRC PCS meeting.* | Loss coefficient external flow pa |

| | Applicability of LST with Respect to Phenomenon | Validation of Modelling Method and/or WGOTHIC | Use of Validation Results in Evaluation Model | How Uncertainty is Handled |
|---|---|---|---|---|
| | | LST - used constant loss coefficient for all predictions | Nominal loss coefficient used; lack of sensitivity | Negligible effect due to weak sensitivity to external Kloss |